Programy finansowane z Funduszy Strukturalnych

FNP

Gluon saturation in dijet production in p-Pb collisions at Large Hadron Collider

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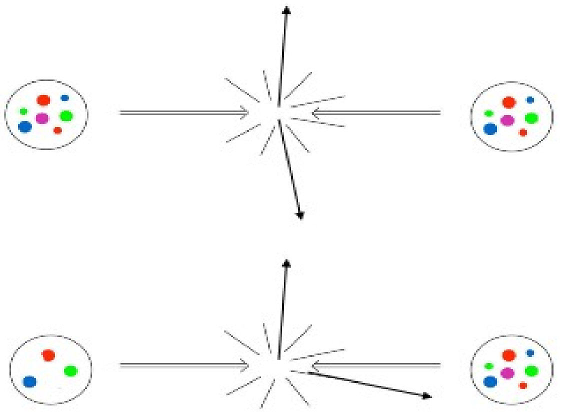
Grant: HOMING PLUS/2010-2/6 of FNP

Based on:

arXiv:1205.5035 K.K, Sebastian Sapeta.
Paper accepted to PRD

LHC as a scaner of gluon

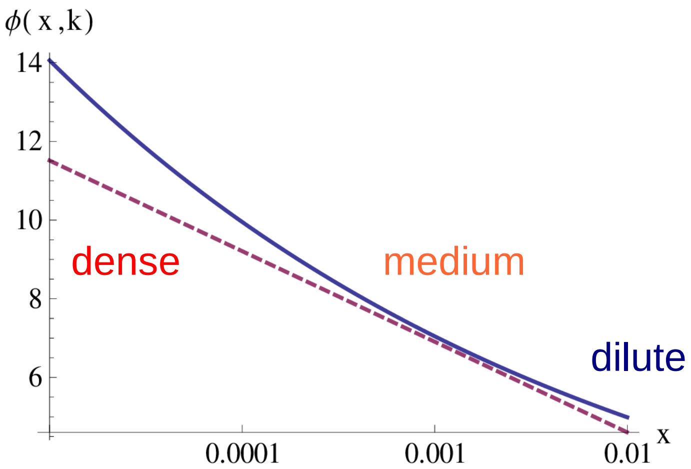
$S = 2P_1 \cdot P_2$



central-central i.e.
medium-medium

forward-central i.e.
dilute – dense

From C. Marquet



$$x_1 = \frac{1}{\sqrt{S}}\left(p_{t1}e^{y_1} + p_{t2}e^{y_2}\right) \xrightarrow{y_1 \sim 0,\, y_2 \gg 0} \sim 1$$

$$x_2 = \frac{1}{\sqrt{S}}\left(p_{t1}e^{-y_1} + p_{t2}e^{-y_2}\right) \qquad \ll 1$$

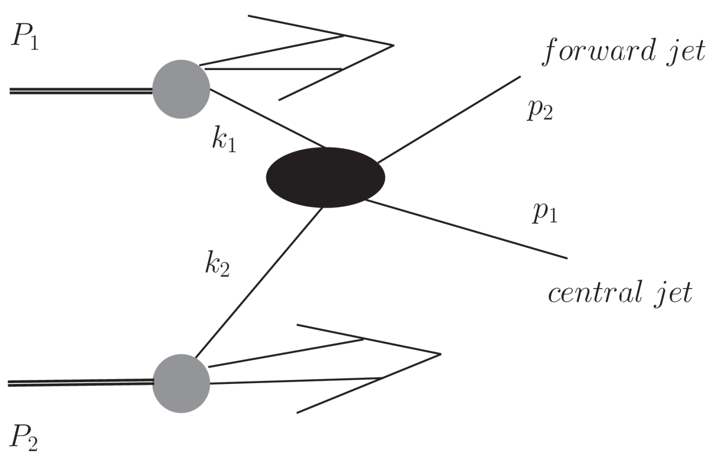
High energy prescription and forward-central dijets

Deak, Jung, Hautmann Kutak
JHEP 0909:121,2009

$$\frac{d\sigma}{dy_1 dy_2 dp_{1t} dp_{2t} d\phi} = \sum_{a,c,d} \frac{p_{t1} p_{t2}}{8\pi^2 (x_1 x_2 S)^2} \overline{|\mathcal{M}_{ag\to cd}|}^2 x_1 f_{a/A}(x_1,\mu^2)\, \phi_{g/B}(x_2, k_t^2, \mu^2) \frac{1}{1+\delta_{cd}}$$

Gauge inv. ME with off shell initial state gluons. More on this P. Kotko and A. van Mameren

$$S = 2P_1 \cdot P_2$$



- *Resummation of logs of x and logs of hard scale*
- *Knowing well parton densities at largr x one can get information about low x physics*
- *Framework goes recently under name ...de framework”*

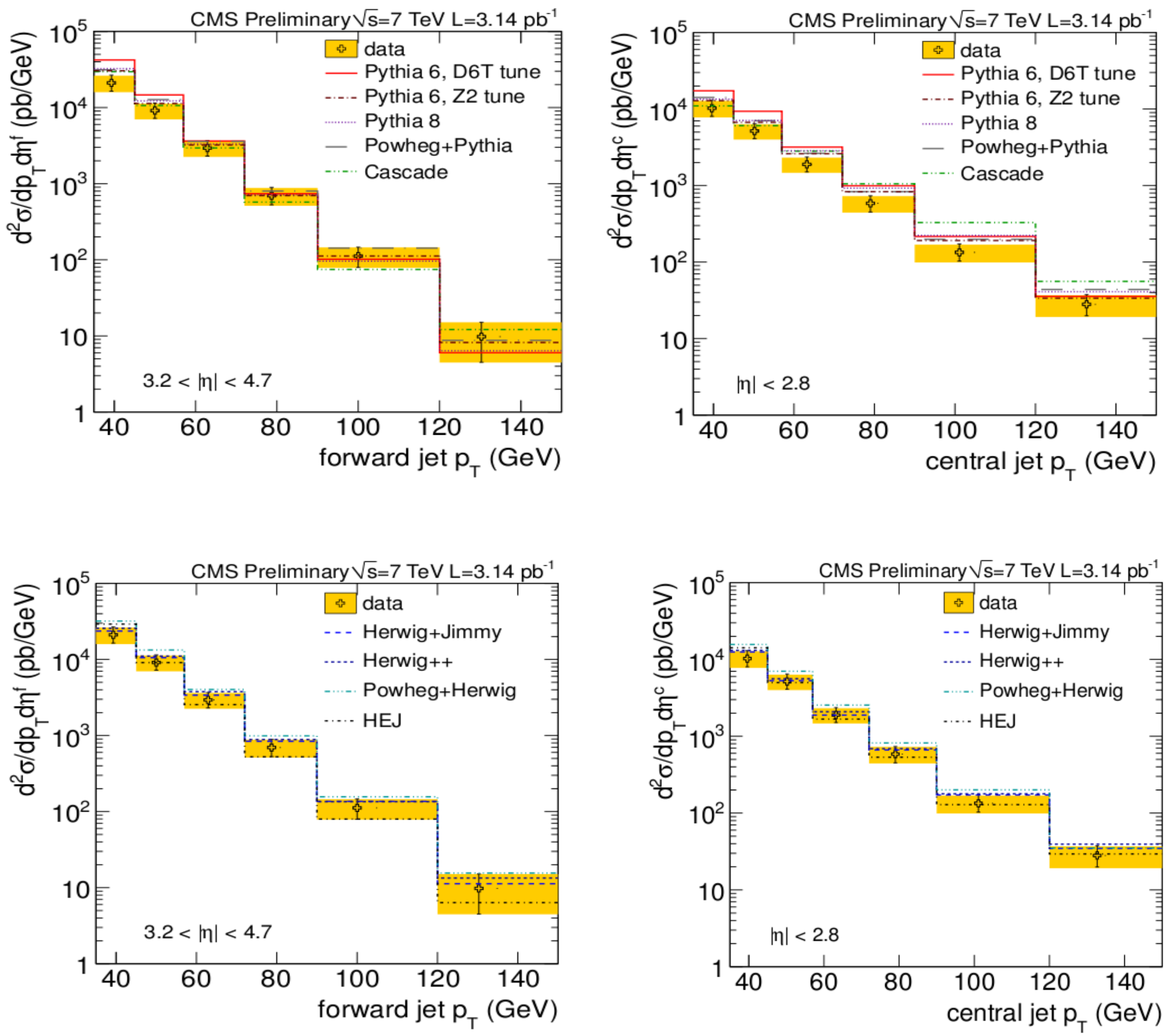
$$x_1 = \frac{1}{\sqrt{S}}\left(p_{t1} e^{y_1} + p_{t2} e^{y_2}\right) \xrightarrow{y_1 \sim 0,\, y_2 \gg 0} \sim 1$$

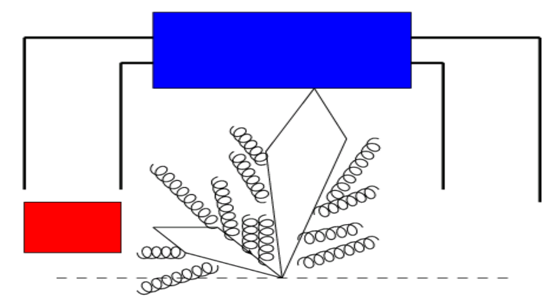
$$x_2 = \frac{1}{\sqrt{S}}\left(p_{t1} e^{-y_1} + p_{t2} e^{-y_2}\right) \qquad \ll 1$$

$$k_1^\mu = x_1 P_1^\mu$$

$$k_2^\mu = x_2 P_2^\mu + k_t^\mu$$

Forward central – jet production





- *HEJ and Cascade based on unordered in k_t emissions but use different parton densities*
- *Herwig and PYTHIA use k_t odered shower but differ in approximations in ME and ordering conditions in shower*

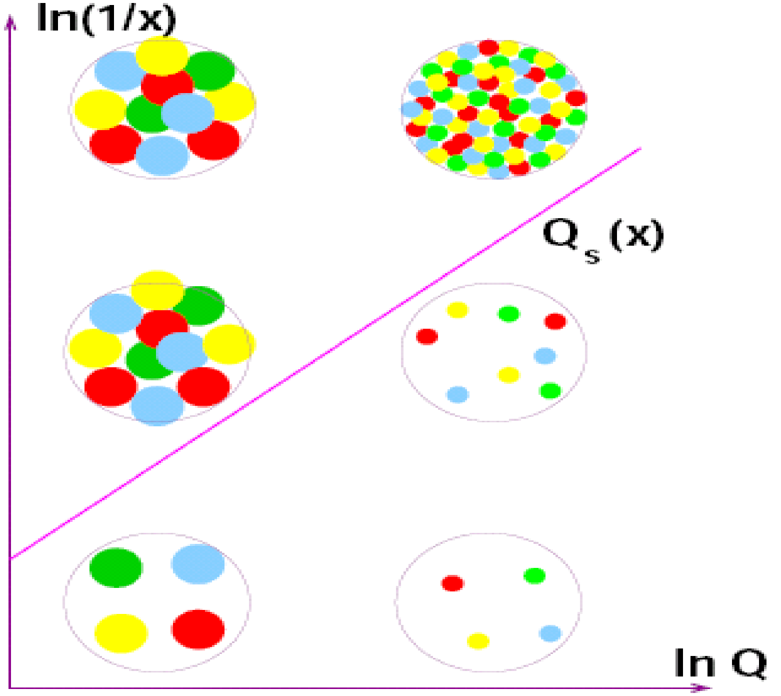
Deak, Jung, Hautmann, Kutak,' 10

Observable sensitive to saturation of gluon density

Kharzeev, Levin,McLerran '05, Marquet '07

High energy factorization and saturation

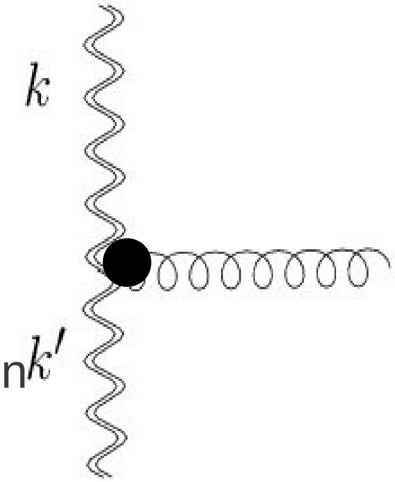
Saturation – state where number of gluons stops growing due to high occupation number.
More generally saturation is an example of percolation which has to happen since partons have size $1/k_t$ and hadron has finite size



Cross sections change their behavior from power like to logarithmic like.

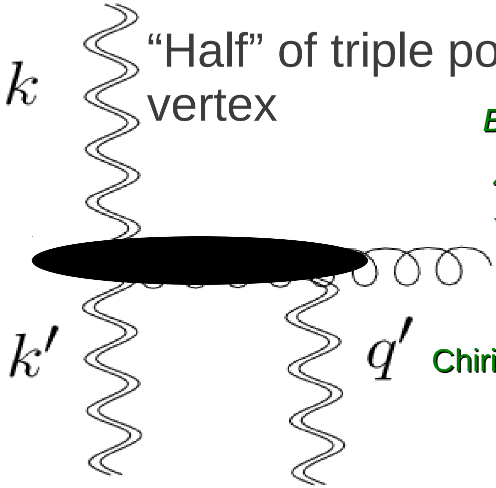
On microscopic level it means that gluon apart splitting recombine

splitting



Linear evolution equation

recombination



"Half" of triple pomeron vertex

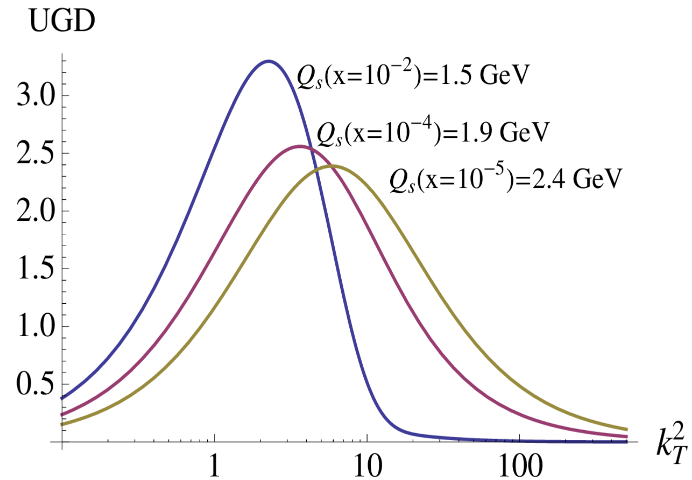
Bartels,Wusthoff

Z.Phys. C66 (1995) 157-180

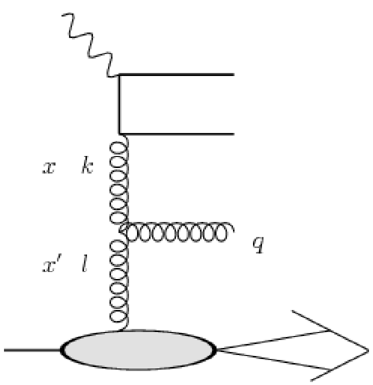
Nonlinear evolution equations
BK, JIMWLK
CGC framework
DIPSY

Chirilli,Szymanowski,Wallon '10

The BK equation for unintegrated gluon density in the momentum space

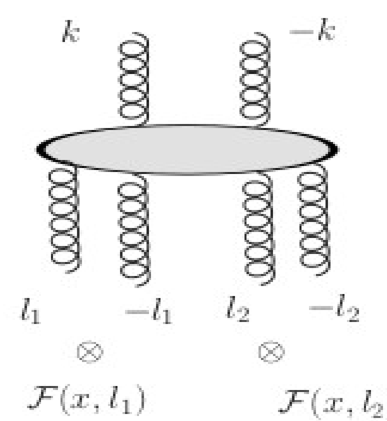


$$\frac{\partial \mathcal{F}_{BK}(x,k^2)}{\partial \ln 1/x} = \frac{N_c\alpha_s}{\pi}\int_0^\infty \frac{dl^2}{l^2}\left[\frac{l^2\mathcal{F}_{BK}(x,l^2)-k^2\mathcal{F}_{BK}(x,k^2)}{|k^2-l^2|}+\frac{k^2\mathcal{F}_{BK}(x,k^2)}{\sqrt{(4l^4+k^4)}}\right]$$
$$-\frac{\alpha_s^2}{R^2}\left\{\left[\int_{k^2}^\infty \frac{dl^2}{l^2}\mathcal{F}_{BK}(x,l^2)\right]^2+\mathcal{F}_{BK}(x,k^2)\int_{k^2}^\infty \frac{dl^2}{l^2}\ln\left(\frac{l^2}{k^2}\right)\mathcal{F}_{BK}(x,l^2)\right\}$$



Kutak, Kwiecinski '03; Nikolaev, Scheffer '04

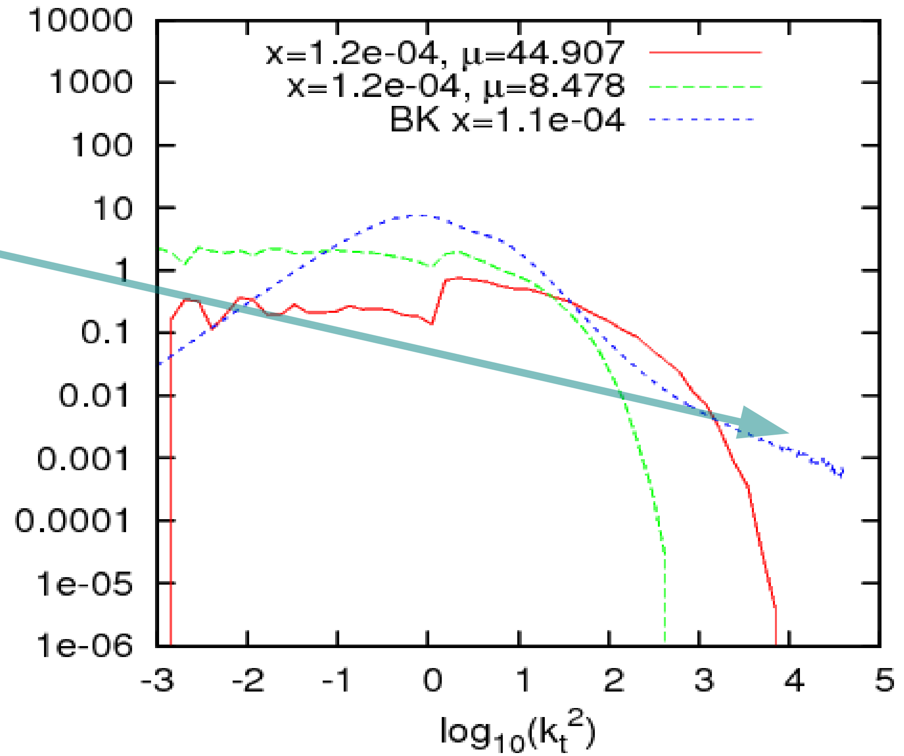
TPV



$$\mathcal{V}(k,-k;l_1,-l_1,l_2,-l_2)=\frac{\pi\alpha_s^2}{N_cR^2}\Big[2\theta(l_1^2-k^2)\theta(l_2^2-k^2)+k^2\ln\frac{l_1^2}{l_2^2}\delta(l_1^2-k^2)\theta(l_2^2-l_1^2)$$
$$+k^2\ln\frac{l_2^2}{l_1^2}\delta(l_2^2-k^2)\theta(l_1^2-l_2^2)\Big]$$

Forward physics as the way to constrain gluon both at large and small pt

- Too flat behaviour of at large kt
- Lack of saturation in CCFM small k_t



More on CCFM
M. Slawinska's talk

Needed framework which unifies both correct behaviors

Final states and saturation

Original formulation of BK or BFKL- difficult to address final state problem. One of possible solutions is to combine physics of BK with CCFM

$$\mathcal{F}(x,k^2,p) = \tilde{\mathcal{F}}_0(x,k^2,p) + \bar{\alpha}_s \int \frac{d^2\mathbf{q}}{\pi q^2}\int_{x/x_0}^{1} \frac{dz}{z}\theta(p-q\,z)\Delta_{ns}(z,k,q)\left\{\mathcal{F}\left(\frac{x}{z},|\mathbf{k}+\mathbf{q}|^2,q\right) - \frac{\pi\alpha_s^2}{4N_cR^2}q^2\delta(q^2-k^2)\nabla_q^2\left[\int_{q^2}^{\infty}\frac{dl^2}{l^2}\ln\frac{l^2}{k^2}\mathcal{F}(x/z,l^2,l)\right]^2\right\}$$

p – linked to some hard scale

coherence

saturation

Kutak '12, JHEP
Kutak, Golec-Biernat,Jadach,Skrzypek '12 JHEP

More on this on example of BK for WW gluon density: D. Toton's talk

Jets and saturation

S.Sapeta. KK
PRD

- Another solution it to follow Kwiecinski-Martin-Stasto prescription to include corrections of higer order in ln1/x
- High energy factorization is an approximation. More general framework given by: F. Dominguez, C. Marquet, F. Huan, Xiao

The equation for unintegrated gluon density with corrections reads:

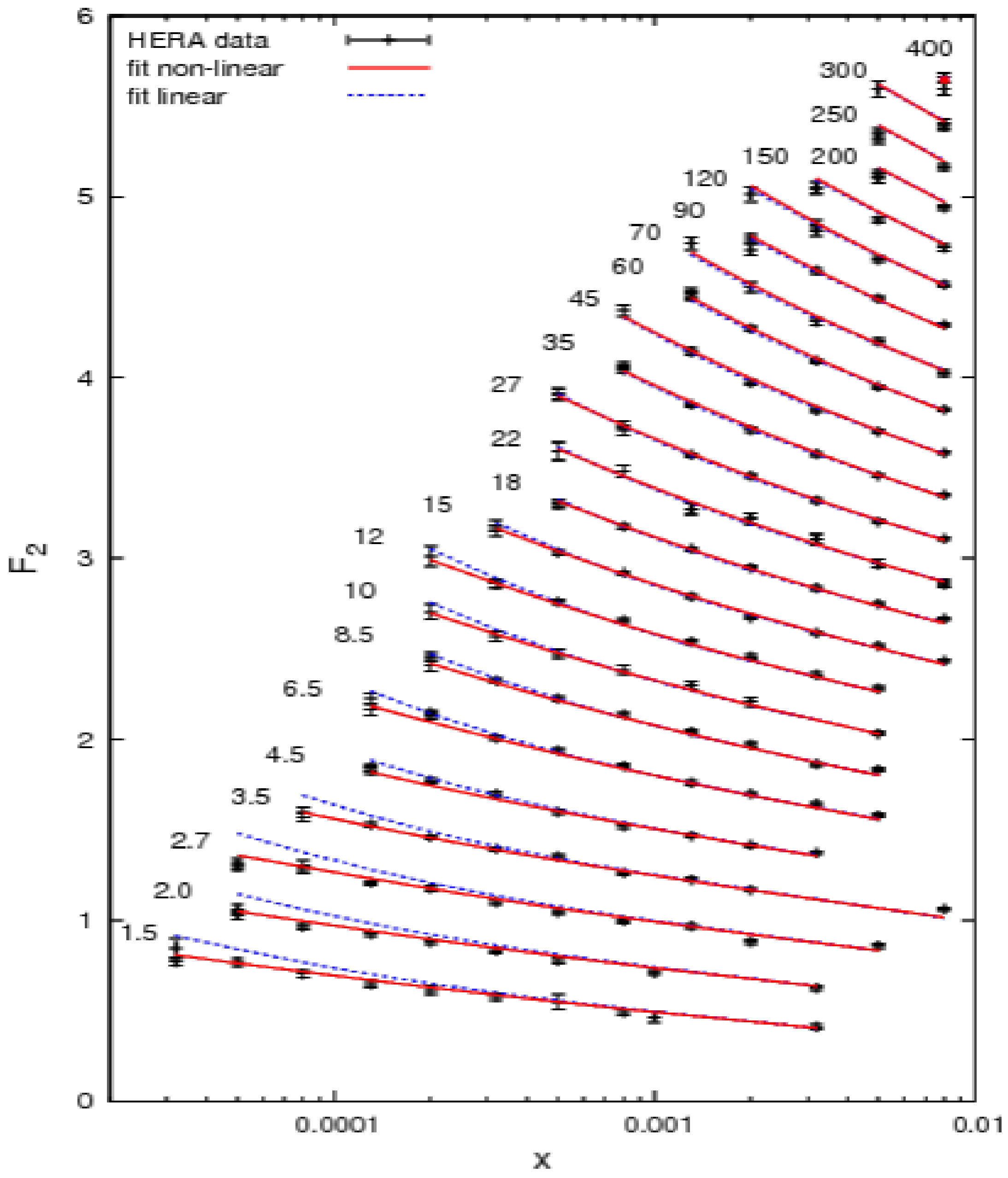
$$
\begin{aligned}
\mathcal{F}_p(x,k^2) \;=\; & \mathcal{F}_p^{(0)}(x,k^2) \\
& + \frac{\alpha_s(k^2)N_c}{\pi}\int_x^1 \frac{dz}{z}\int_{k_0^2}^{\infty}\frac{dl^2}{l^2}\left\{\frac{l^2\mathcal{F}_p(\frac{x}{z},l^2)\,\theta(\frac{k^2}{z}-l^2)\;-\;k^2\mathcal{F}_p(\frac{x}{z},k^2)}{|l^2-k^2|}+\frac{k^2\mathcal{F}_p(\frac{x}{z},k^2)}{|4l^4+k^4|^{\frac{1}{2}}}\right\} \\
& + \frac{\alpha_s(k^2)}{2\pi k^2}\int_x^1 dz\left(P_{gg}(z)-\frac{2N_c}{z}\right)\int_{k_0^2}^{k^2} dl^2\,\mathcal{F}_p(\frac{x}{z},l^2) \\
& - \frac{2\alpha_s^2(k^2)}{R^2}\left[\left(\int_{k^2}^{\infty}\frac{dl^2}{l^2}\mathcal{F}_p(x,l^2)\right)^2+\mathcal{F}_p(x,k^2)\int_{k^2}^{\infty}\frac{dl^2}{l^2}\ln\left(\frac{l^2}{k^2}\right)\mathcal{F}_p(x,l^2)\right]
\end{aligned}
$$

Kwiecinski,Kutak '03

Corrections of higher orders Included. Kin. Constr DGLAP spf

Andersson, Gustafson,Sammuelsson '96
Kwiecinski, Martin, Sutton '96

Hints for saturation in F_2 data



S.Sapeta. KK PRD

Fit of BK-DGLAP and BFKL-DGLAP to combined H1-ZEUS data

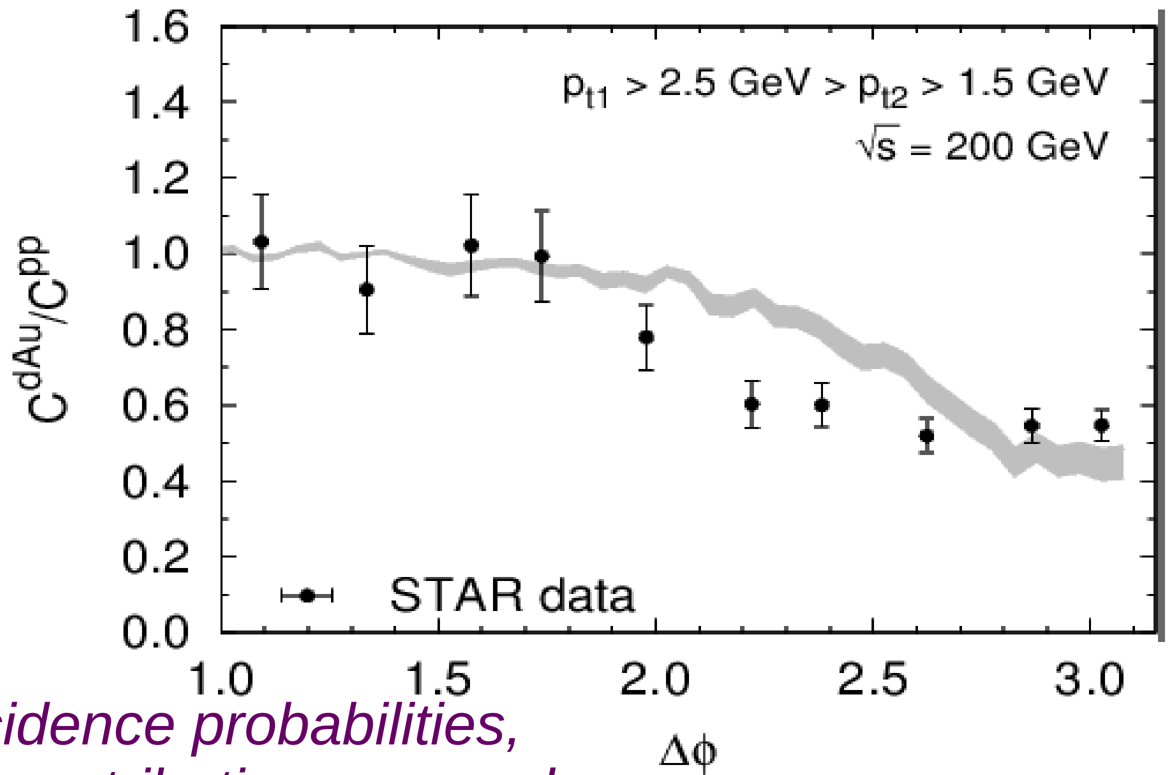
Very good description with BK-DGLAP in range $Q^2 > 1.5\ \mathrm{GeV}^2$

$$\chi^2 = 1.73$$

Very good description with BFKL-DGLAP in range $Q^2 > 4.5\ \mathrm{GeV}^2$

$$\chi^2 = 1.5$$

Hints for saturation in RHIC data



S.Sapeta. KK PRD

Ratio of coincidence probabilities, uncorrelated contribution removed

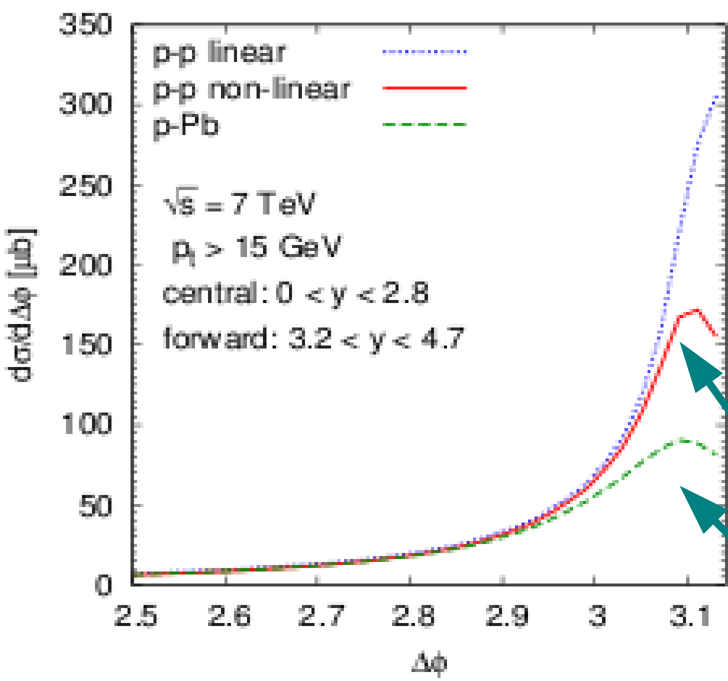
where $C(\Delta\varphi) = N\ pair\ (\Delta\varphi)/N\ incl$

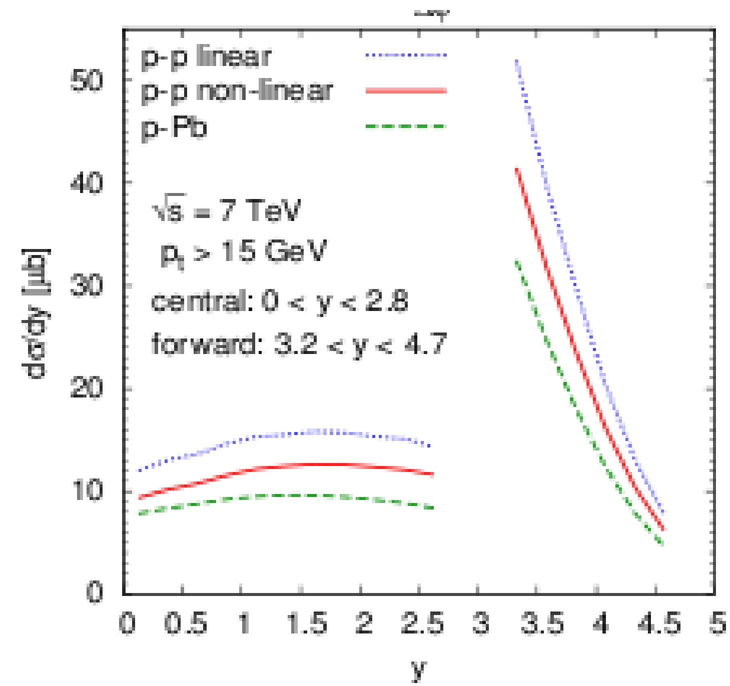
J. L. Albacete, C. Marquet, Phys. Rev. Lett. 105 (2010) 162301.

A. Stasto, B., Xaio, F. HuanPhys.Lett. B716 (2012) 430-434

Signatures of saturation in p-p and p-Pb

S.Sapeta. KK PRD



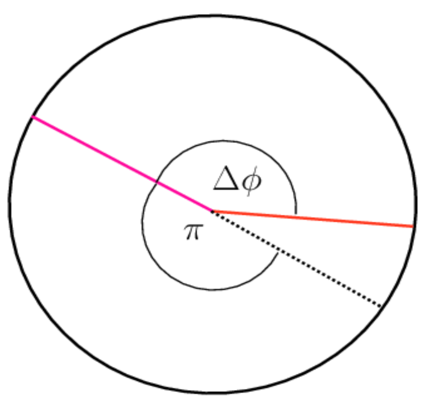


Reflects~ k^2

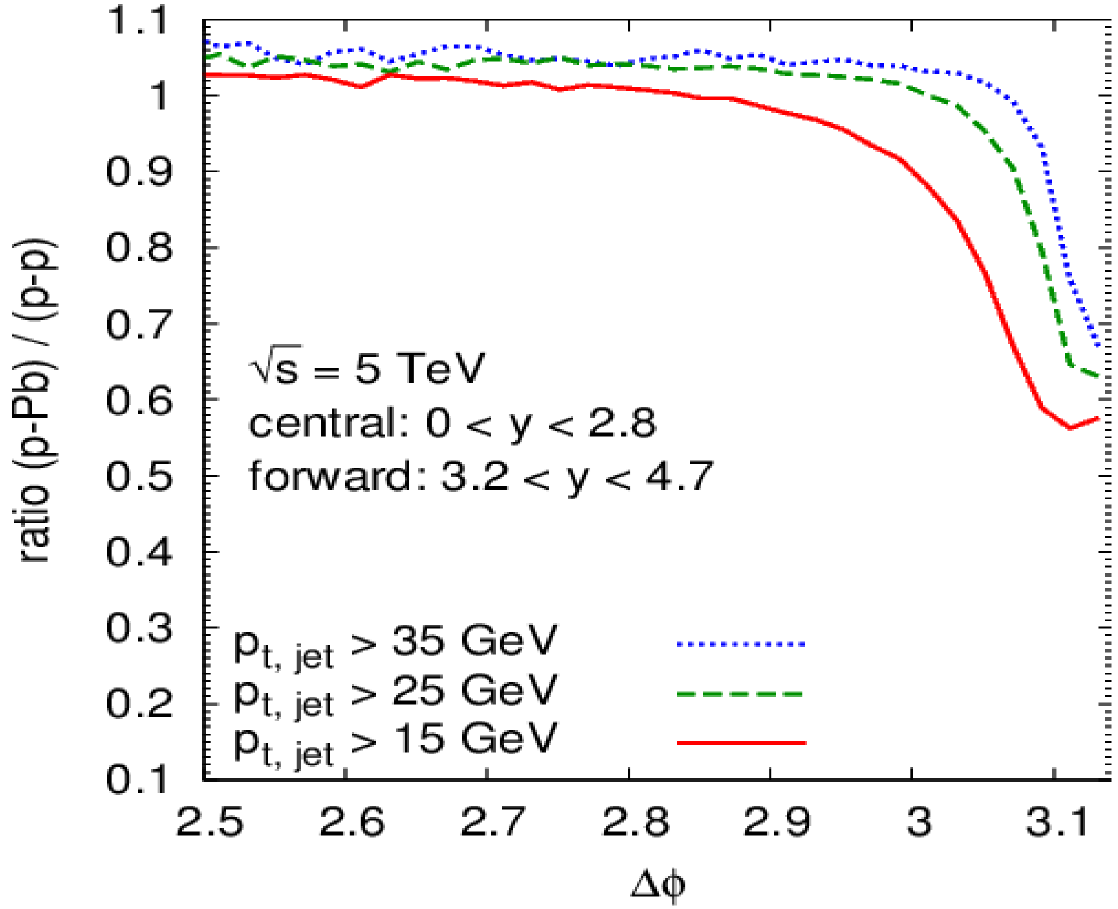
behavior of gluon at small k^2

Observable suggested to study BFKL effects

Sabio-Vera, Schwensen '06



Signatures of saturation: p-Pb/p-p at 5 TeV



Conclusions and outlook

- *With help of LHC there comes opportunity to test parton densities both when the parton density is probed at low x and low enough kt.*

- *HERA and RHIC data further gives some hints for saturation*

- *Results based on BK/DGLAP approach predicts saturation in p-Pb and sugges tits presence in p-p*